

Singular Vector Based Observation Targeting

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Persons Visited

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LONG-TERM GOAL

Evaluation and improvement of adaptive observation techniques that aim at improving weather forecasts in the range 0–5 days with a particular focus on severe weather events.

OBJECTIVES

- A) attend workshop on predictability, April 23–25, Monterey CA
- B) attend THORPEX planning meeting, April 26–27, Monterey CA
- C) attend DRI predictability workshop, May 3–4, Boston, MA

APPROACH

Predictability workshop, Monterey: The purpose of the predictability workshop in Monterey was to summarize current knowledge and to identify open questions. Chuck Leith gave a review talk summarizing the history of predictability. He focussed on estimates of predictability obtained from turbulence theory. The meeting comprised sessions on (1) characteristics of initial perturbations that influence predictability (facilitated by Jeff Anderson), (2) rate of perturbation growth for various fields (facilitated by Martin Ehrendorfer), (3) characteristic scales and scale interaction of error growth (facilitated by Dave Baumhefner), (4) mechanisms of error growth (Isla Gilmour), (5) model error (facilitated by Dave Stensrud), (6) ensemble generation and utilization (facilitated by Steve Tracton), (7) optimization of observing strategies and targeting (facilitated by Rolf Langland), (8) definition of meaningful NWP goals (facilitated by Ron Errico). A summary paper of this workshop will be published. Ron Errico is writing a first draft which will be circulated to all workshop participants for input.

In session 1, the necessity to constrain initial perturbations in probabilistic forecasts was discussed.

We know little about the slow manifold for realistic NWP models, especially about balances in the physical processes such as convection. This limits our ability to formulate appropriate constraints.

The question was raised whether there are techniques of sampling the initial pdf which are especially suitable for probabilistic forecasts of “extreme events”. In the discussion, several different definitions of “extreme events” were collected: (i) a severe weather event, e.g. a storm causing casualties, (ii) rare event with respect to climatology, (iii) unlikely event given the initial pdf, (iv) an event in which extreme limits of the model physics are encountered. The optimal strategy of probabilistic forecasting will depend on the adopted definition of an extreme event.

Session 2 revolved around the Lorenz diagramme showing forecast error growth and intrinsic error growth determined from lagged forecasts. Martin Ehrendorfer showed latest results from Adrian Simmons (ECMWF). The error doubling time for 500 hPa height decreased to a value of about 1.5 days in the early 90’s and stayed around this level since. Anders Persson pointed out that the error growth is linked to the activity of the model. Underactive (overactive) models are expected to exhibit a larger (smaller) error doubling time. Error doubling times for other operational models were not known. The concept of an error doubling time was questioned as the growth curve deviates from an exponential at small forecast ranges. Another important aspect that deserves attention is the case to case variability of the predictability time scale. For many applications an average value over many cases may be irrelevant.

In session 3, it was noted that errors with very different spatial scales cause similar forecast errors (in spectral space) at a forecast lead time of ≥ 3 days. However, it seems difficult to disentangle the contribution of error at different scales as any large scale error will cause small scale errors by advection errors of small scale features. Errors are often geographically localized which is missed by the spectral description. Isla Gilmour presented evidence from θ -statistics that the error growth becomes nonlinear already at the 1 day range in localized regions. Furthermore, it was discussed whether there is a general definition of a limit of predictability. The range of forecast times over which a forecast will be useful is user dependent. If the forecast contains the same information as climatology it will be useless for everybody.

In session 4, the discussion about a linear phase of error growth was continued. There seems to be a paradox regarding the apparent success of targeting observations. Nonlinearity of perturbation growth is expected to be important already after 1 day according to Isla Gilmour’s results. Current targeting approaches assume linear perturbation growth over a typical range of 2 days. It was speculated whether the linear approximation may be still useful to describe error growth even if error growth becomes nonlinear.

The discussion of session 5 covered different attempts to estimate model error and their shortcomings (drift vectors, initial tendency errors, deviation of model climate from observed climate). Lenny Smith remarked that the attempt to separate model error from initial condition error is linear reasoning as a better model results in smaller initial condition error via the first guess fields which become more accurate. The inability to find a shadowing trajectory sets a limit to 4dvar assimilation periods (Lenny Smith) but is not necessarily a proof that a shadowing trajectory does not exist as the search may fail due to an increasingly complex topography of the cost function when the period is extended (Martin Leutbecher).

In session 6, it was recommended to formulate as appropriate goal to supply useful (probabilistic) forecasts rather than reliable forecasts. In session 7, Anders Persson stressed the role of data monitoring: forecast busts may be due to lack of observations, but also due to erroneous observations accepted in the assimilation. OSSEs were seen as a method to identify critical gaps in the observing system. A joint project of NCEP/NASA was mentioned, that aims at verifying an OSSE system.

Mel Shapiro showed fields subjectively analysed from sounding data at a spatial resolution of 30 km obtained during recent field experiments over the Pacific. There is evidence for a large error of representativeness and considerable deviation from geostrophic balance. Craig Bishop suggested that the error of representativeness is large near features such as fronts.

Dave Baumhefner showed results of numerical experiments with ensembles that assess the feasibility of targeting observations in the nonlinear regime of perturbation growth. Two ensembles are compared that are identical in the initial perturbations except in a localized region. In this region the initial error is set to zero in one ensemble. The local improvement of the initial conditions results in increased certainty that moves downstream but later (after 3 days) also regions with increased uncertainty appear. At a range of 5 days, regions with increased uncertainty cover about the same area as regions with reduced uncertainty.

Thorpex Planning Meeting: The purpose of the THORPEX meeting was to initiate the preparation of a science plan for the project. The 2 day meeting was composed of a series of short presentations and discussions that contributed scientific issues relevant for THORPEX. The meeting was chaired by Bob Gall and Alan Thorpe.

Dave Baumhefner presented the assessment of locally improving the initial conditions using ensembles (see above). In the discussion, Chris Snyder suggested a strategy that optimally reduces the uncertainty of the analysis to improve the skill for several forecast ranges and different verification regions. George Kiladis spoke about the tropical extratropical interaction in the Pacific wave guide. In the discussion, numerical experiments were proposed to assess the impact of moisture in the ITCZ on subsequent downstream development. Cliff Mass presented an evaluation of different analyses based on comparison with observations. Nancy Baker spoke about the sensitivity to observations. High values of sensitivity indicate a large sensitivity to observational error. Therefore, intermediate values of the sensitivity are preferable. An objective method to determine the optimal intermediate value has yet to be determined. Martin Leutbecher presented results on observation targeting based on singular vectors. In the discussion, Chris Snyder proposed to distribute the observations also in time. (possible techniques, Phil Merrilees: partially evolved singular vectors; Craig Bishop: combination of Ensemble Transform Kalman Filter and singular vectors). Zoltan Toth showed results from the WSRP experiments. Chris Snyder proposed research on ensemble Kalman filtering. He estimated that a test with an operational model is possible with moderate resources (in contact with Jeff Anderson and Craig Bishop).

Francois Gerard spoke about the EUCOS perspective. National weather services in Europe are primarily interested in upgrades of the observing network that lead to improvements of the European forecast in the range up to three days. He showed plans to increase the number of automated soundings released from cargo ships to about 25 per day on the Atlantic. The aim is to concentrate the soundings in regions that are likely to be sensitive using seasonally averaged adjoint sensitivities. Jim Purdom sketched qualities of current and future satellite observing systems. Phil Merriles pointed out

that THORPEX may be an opportunity to compare satellite observations with in situ observations to learn more about the error characteristics of the different instruments over the oceans. Thierry Pulpin presented the development of an active driftsonde which could be steered by changing the level of the balloon exploiting directional wind shear. The platform would be available in 2005. Currently it is planned to observe around 10 cases in a 3 month period with up to 5 balloons operating in each case. The position and frequency of the drops could be influenced. Hal Cole gave an overview of the driftsonde developed jointly by NCAR/ATD and Vaisala. Test flights are scheduled for August 2001 from Tillamook, Oregon and September 2001 from Hawaii. The frequency of the drops could be influenced. Roland Stull presented the rocketsonde project. With this system, soundings would be obtained in the east Pacific twice daily at a horizontal spacing of about 900 km. Tad McGeer spoke about progress in the development of the aerosonde. The range of this platform could be improved by launching it from ships. The quality of wind velocity measurements obtained with this platform was questioned by Mel Shapiro. Each wind velocity measurement requires to fly an S-shaped track. Mel Shapiro presented examples of unbalanced motion and large small scale variability observed over the Pacific (see above). He envisaged that future space borne Laser could provide accurate cloud top heights, which could be used to improve the accuracy of the height assignment of cloud motion winds. In the discussion Zoltan Toth mentioned that NCEP is working on accounting for the horizontal drift of radiosondes in the assimilation system (the horizontal drift can be as large as 200 km in the stratosphere).

Roger Pielke facilitated a discussion on the verification of the impact. Kerry Emanuel proposed to use a standard cost-benefit analysis to optimize the observing network.

DRI predictability meeting, MIT: The DRI meeting focussed on the themes (i) perspectives of predictability, (ii) ensemble forecasting and (iii) data assimilation. In session (i), Roger Samelson spoke about Floquet vectors and Lyapunov vectors and Prashant Sardeshmukh presented a linear stochastic view of climate variability and predictability. In session (ii), Tim Palmer illustrated aspects of ensemble forecasting for the atmosphere with results from ECMWF. Denny Kirwan showed results from ensembles of Lagrangian characterizations of the ocean surface flow. In session (iii), Ron Errico and Andrew Bennett spoke about data assimilation with an emphasis on the atmosphere and ocean, respectively.

In the complementary poster session I presented first results on Hessian singular vectors computed for different modifications of the observing network. I discussed with Carolyn Reynolds and Craig Bishop whether the singular value spectra for the different observing networks would be a measure of the expected forecast error. And how this presumed link could be investigated via data denial experiments.

TRAVEL COMPLETED

Table: Summary of visits conducted under this VSP.

Person Visited	Position	Inst./ Conf.	Location	S/T Purpose	Dates
Rolf Langland	Scientist	NRL	Monterey CA	pred. workshop	04/23–25/01
Rolf Langland	Scientist	THORPEX	Monterey CA	meeting	04/26–27/01
Scott Sandgate	DRI Manager	ONR/DRI	Boston MA	workshop	05/03–04/01

RESULTS

predictability workshop Monterey: Views about our current understanding of fundamental issues in predictability of the atmosphere were exchanged. Areas in which we lack knowledge were identified: characterization of the slow manifold; relevance of nonlinearity for forecast error growth in the early range; identification of model error/ its relevance/ its representation in probabilistic forecasts; the characterization of analysis errors.

THORPEX meeting: The main aim of THORPEX appears to be the evaluation of an upgrade of the routine observing network. The status of different candidate observing platforms for this upgrade was presented. The objective in forecast skill improvement envisaged by the US community is broad (hemispheric, up to 10 days). Demands at the national weather services in Europe are more specific (improvement for Europe in the range up to 3 days). Supplementary in situ observations may also be used to characterize background/analysis errors, study errors of satellite instruments over the oceans.

DRI predictability meeting: The mutual understanding of the scientific issues on which the different groups in the DRI work was improved.

IMPACT/APPLICATIONS

Results of work that Tim Palmer and I presented at the DRI workshop about singular vectors computed with Hessian metric received great interest. Further experiments will be set up to address questions raised at the meeting (spatial resolution, role of background error covariances, structure of singular vectors in other cases)

Mel Shapiro and I consider to collaborate on studying the impact of representativeness error of drop-sonde observations using existing data sets with closely spaced soundings.

TRANSITIONS

Improvements in predicting the weather are desirable for a variety of applications. Research on predictability enables to define realistic goals for weather forecasting. Intelligent upgrades of the observing network may be an efficient way to achieve certain forecasting objectives.

RELATED PROJECTS

The Hemispheric Observing System Research and Predictability Experiment (THORPEX, www.nrlmry.navy.mil/~langland/THORPEX_document/Thorpe_x_plan.htm)